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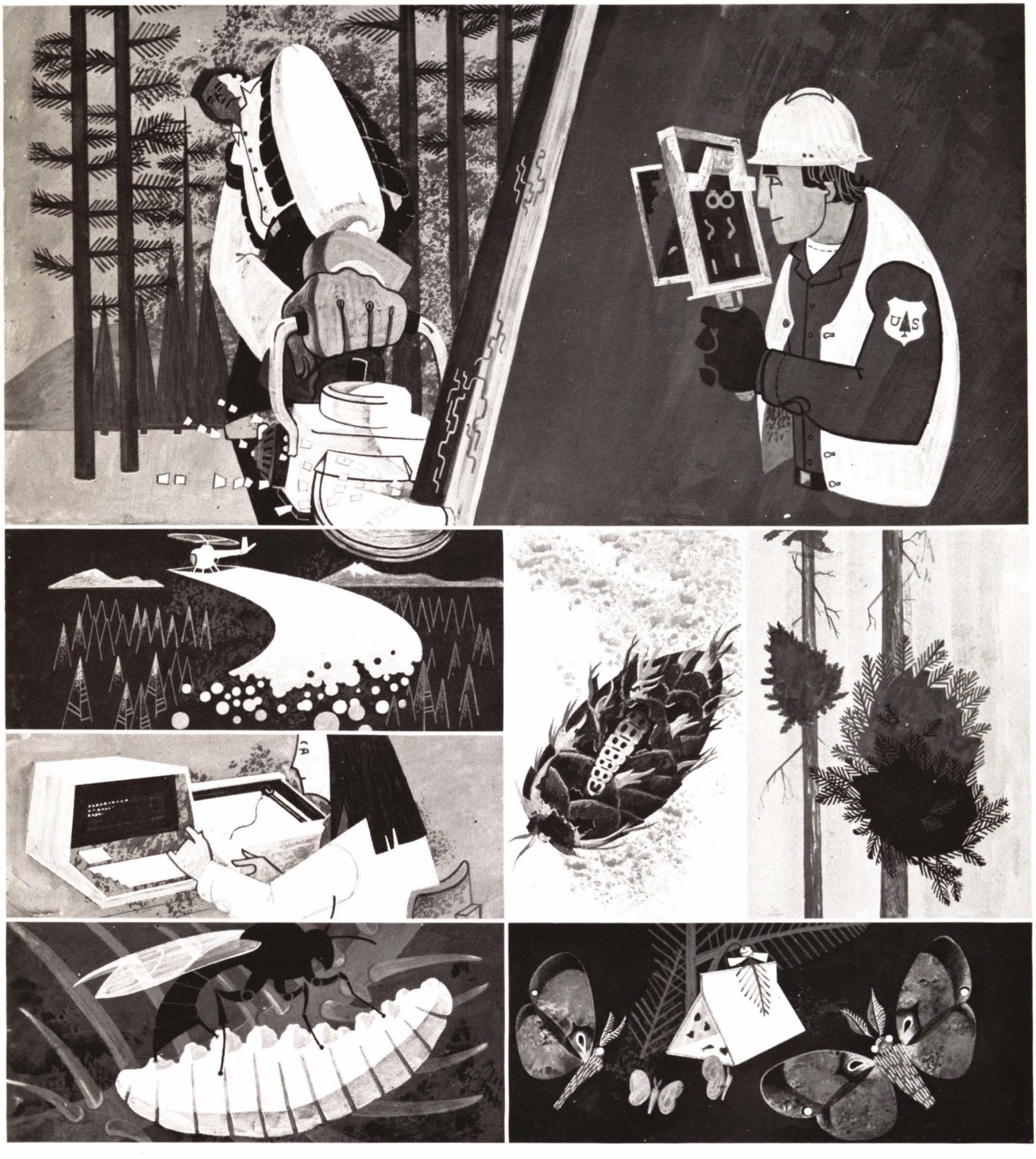
Forest Pest Management

Methods Application Group

Fort Collins,
Colorado 80524

MAPPING INSECT DEFOLIATION IN EASTERN HARDWOOD FORESTS WITH COLOR-IR AERIAL PHOTOS

— A PHOTO INTERPRETATION GUIDE —



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Report No. 86-2

3400
February 1986

MAPPING INSECT DEFOLIATION IN EASTERN HARDWOOD FORESTS WITH COLOR-IR AERIAL PHOTOS

- A PHOTO INTERPRETATION GUIDE -

by

J.D. Ward, R.E. Acciavatti, and W.M. Ciesla[1/]
USDA Forest Service

ABSTRACT

Procedures for using color infrared (CIR) aerial photographs for classification and mapping of insect-caused defoliation in eastern hardwood forests are presented with special reference to the gypsy moth, Lymantria dispar L. Defoliation classification, methods of map transfer, and assessment of insecticide treatments are discussed. In addition, conditions which might be confused with defoliation, resulting in photo interpretation error, are described and illustrated. These techniques apply to small and conventional format photos as well as high altitude panoramic photos.

INTRODUCTION

The hardwood forests of the Eastern United States have always been subject to periodic outbreaks by defoliating insects. Widespread outbreaks may cause a number of social and economic impacts. Most outbreaks of native eastern hardwood defoliators, such as the fall cankerworm, Alsophila pometaria (Harris), forest tent caterpillar, Malacosoma disstria Hbn., and linden looper, Erannis tiliaria, Harr., are usually short lived. However, the last decade the gypsy moth, Lymantria dispar L., a pest introduced from Europe, has caused widespread defoliation every year in the eastern United States and has received considerable public attention. From 1980 to 1985, gypsy moth defoliation was reported in 13 states with a total area of defoliation averaging over 5.8 million acres annually.

1/The authors are respectively: Supervisory Entomologist, Southern Region, Doraville, GA; Entomologist, Northeastern Area, Morgantown, WV; and Group Leader, Forest Pest Management/Methods Application Group, Fort Collins, CO.

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EXPERIMENT STATION

Defoliation of hardwood forests is one of the most conspicuous types of forest damage. The appearance of thousands of acres of hardwood forests in early summer with little or no foliage can be striking both from the ground and the air (Figure 1). Accurate and timely assessment of forest defoliators on an annual basis is necessary to monitor the status and trend of outbreaks, plan suppression projects, and evaluate their effectiveness. Traditionally, aerial sketch mapping has been the technique most widely used to map defoliation; however, during the past 15 years, aerial photography has been used to help meet these needs.

Figure 1 - Defoliation of hardwood forests in southern Alabama by forest tent caterpillar.

This guide describes procedures for using color infrared aerial (CIR) photographs to locate and map hardwood defoliation using visual photo interpretation techniques. These procedures can be used with small format, conventional 9-inch, and high altitude panoramic aerial photography taken by

NASA earth resources reconnaissance aircraft. It is not intended as an all inclusive user manual on photo interpretation, but rather to serve as a reference source for interpretation and mapping of hardwood defoliation. Theoretical and detailed discussions of the technology are not included, but can be obtained from the references provided.

THE AERIAL PHOTOS

FORMATS AND SCALES

Almost any good quality color or CIR aerial photograph can show insect defoliation of hardwood forests provided that the photo is taken during the time of year when the damage is visible. Aerial photos of virtually any format can be used for defoliation mapping, including small format 35 mm and 70 mm photos; standard or large format, 9-inch or 9x18-inch photos, and panoramic format. In recent years, defoliation caused by the gypsy moth has been successfully mapped from high altitude panoramic aerial photos taken with a NASA earth resources reconnaissance aircraft. Panoramic photos are of an unusual format with each photo having dimensions of 5-1/2 inches by 39-1/2, 50 or 59-1/2 inches, depending on the model of panoramic aerial camera used.

Because insect defoliation of hardwood forests is a conspicuous type of forest damage, it can be mapped with reasonable accuracy on aerial photos of relatively small photo scale. Defoliation has been mapped on aerial photos taken with 9-inch mapping cameras at photo scales up to 1:16000. Smaller scales are favored because more land area is covered on a single photo and the relationship of defoliation relative to the topographic or cultural features of the landscape are more easily seen. Panoramic aerial photos are unique in that the photo scale gradually changes with an increasing distance from nadir, the point directly underneath the aircraft. Nadir scale for most panoramic aerial photos is 1:30000, whereas at the extreme ends, the photo scale is approximately 1:64000 (Figure 2). Even at these small photo scales defoliated forests are still visible.

COLOR INFRARED FILM

At first glance, scenes taken with CIR film appear as though they were taken on a distant planet. It is different from standard color film in that its dye layers are sensitized to the green, red, and near-infrared portions of the electromagnetic spectrum. Normal color films are sensitized to blue, green, and red light.

Living vegetation, which reflects infrared radiation, appears in various shades of red on CIR film. Red colored objects, such as flowers and dying trees, appear as yellow or yellow green. Defoliated or dead trees appear gray or blue gray (Table 1).

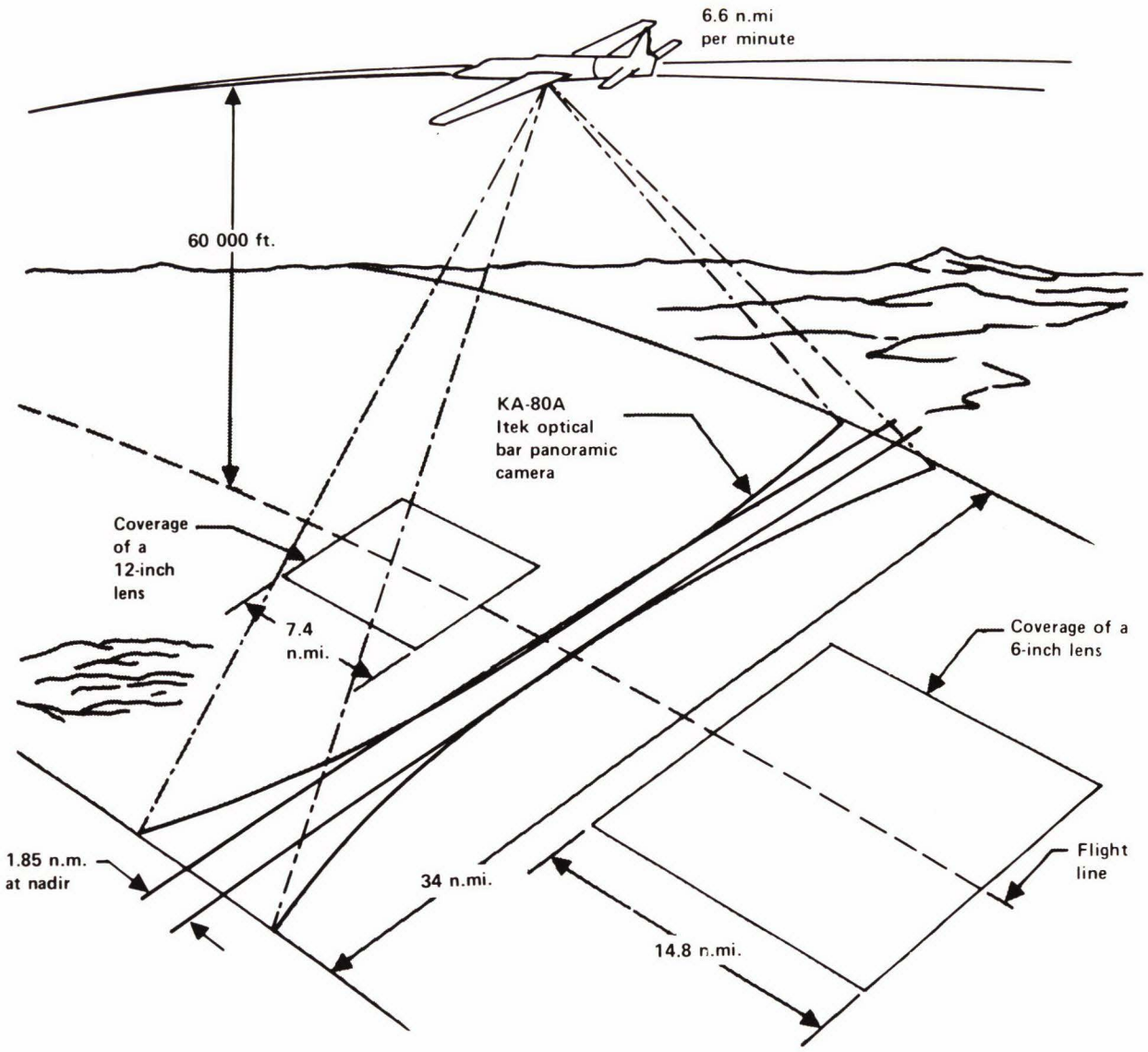


Figure 2 - Comparison of ground coverage for panoramic aerial photos and photos taken with a 9-inch format mapping camera.

Table 1 - Generalized Interpretation Guide to Colors on Color-IR Film as Related to Forest Damage

Subject	Color in Nature or on Color Photos	Color on CIR Photos
Grass, meadows	Light Green	Pink
Healthy deciduous foliage	Medium Green	Brilliant Red
Healthy coniferous foliage	Dark Green	Red brown or Red violet
Chlorotic trees	Yellow green to Yellow	Pink to White
Dying trees with discolored foliage	Yellow to Red	Beige or Pale Yellow
Dead trees with small amount of foliage remaining	Gray	Blue green
Defoliation or mortality of all or a portion of a tree	Gray	Blue gray to Gray

CIR is widely used in resource assessment because it has several advantages over color film for aerial photography. Because CIR is always exposed through a yellow filter, thus eliminating blue light, most atmospheric haze is penetrated and clearer photos are produced. Also, certain features are enhanced on CIR film. For example, water absorbs infrared radiation; therefore, streams and lakes will often appear as dark blue or black on CIR film. This increases the contrast between water and surrounding land and permits edges of waterways to be mapped more accurately. Major forest types are more easily separated on CIR film; hardwood forests photograph bright red; while conifer stands appear as a dark red brown or red violet color.

Certain types of forest pest damage are also enhanced on CIR film. In the case of insect caused defoliation of hardwoods, there is a much greater contrast between the gray of defoliated areas and the bright red of undamaged hardwood forests than can be seen by the naked eye or on color film.

CIR film is designed to be processed to a positive transparency for interpretation on a light table. Transparencies are superior to photo prints because they have higher image resolution and lighting can be adjusted to

compensate for slight variations in exposure. CIR transparencies also present greater contrast between damaged and undamaged areas than do prints, good quality CIR transparencies will actually have a greater contrast than the illustrations provided in this guide.

GETTING READY

PHOTO INTERPRETERS

The most important factor affecting the successful completion of any task is the people that are assigned to it. The qualifications, experience, and dedication which they bring to the project can make all the difference in the world, regardless of how good the photo product may be.

Obviously, people selected to interpret color or color-IR photos must be able to detect subtle changes in color. Color perception deficiencies, especially the ability to discern certain hues of red and green, is rather common among males. Subjecting prospective photo interpreters to a color perception test, such as the American Optical H-R-R- Pseudoisochromatic Plates, is recommended to screen out individuals with a color vision deficiency.

Since insect defoliation in hardwood forests is conspicuous and easily seen on color-IR photos without magnification, individuals with little or no formal training in photogrammetry or photo interpretation can be trained to easily recognize and accurately classify the damage. They must be able to read maps in order to orient themselves both on maps and aerial photographs. They should be familiar with terrain features and vegetation typical of the areas to be surveyed. It is helpful to have some general knowledge about the insect being evaluated, such as its feeding habits, the appearance of damage, host preferences, and patterns of feeding; for example, does the most severe damage occur on ridgetops as opposed to slopes or low lying areas.

EQUIPMENT

Mapping defoliation in hardwood forests using CIR photos can be done readily with only a few items of equipment:

LIGHT TABLE - Since CIR film is normally processed as a transparency, viewing requires a light table. Many commercial models of light tables available and most are suitable for this purpose. Aerial photo transparencies are usually stored on rolls rather than as individual frames, therefore, light tables should be equipped with reels for holding large rolls of film.

MAPS OF THE AREA BEING SURVEYED - An up-to-date set of base maps is necessary on which to plot the location of defoliated areas. USGS 7.5 minute topographic maps with a scale of 1:24,000 are best suited for this purpose. In areas where 7.5 minute coverage is not available, the 15 minute USGS series, with a scale of 1:62,500, will suffice.

PENS OR PENCILS FOR MAP TRANSFER - Any type of hard pencil or pen can be used to transfer the location of defoliated areas seen on photos to maps. If several classes of defoliation are to be mapped, it is usually best to plot them in different colors.

PHOTO INTERPRETATION AIDS - Special computer generated transparent equal area grid overlays are available which compensate for changes in the scale of high altitude panoramic aerial photos. These grids help photo interpreters recognize the spatial relationships of objects on the photography with respect to the same objects presented on a map. Most area measurements can be made directly from 7.5 minute topographic maps or with the use of the grids. The equal area grid overlays are useful in determining approximate acreage and approximate size of features such as a stand of timber, and can be used to measure distances by counting the number of grid intervals between two points (Figure 3).

MONOSCOPIC VERSUS STEREOSCOPIC VIEWING

With most uses of aerial photography, it is necessary to view the photos in stereo in order to obtain a three dimensional image. While it is desirable to view aerial photos in stereo for mapping hardwood defoliation, it is not essential, and reasonably accurate defoliation maps can be prepared without the aid of a stereoscope. A 10X hand lens or simple pocket or mirror stereoscope can be helpful for viewing areas of questionable damage however, or where more accurate delineation of defoliation is needed, such as areas which have been treated with insecticides.

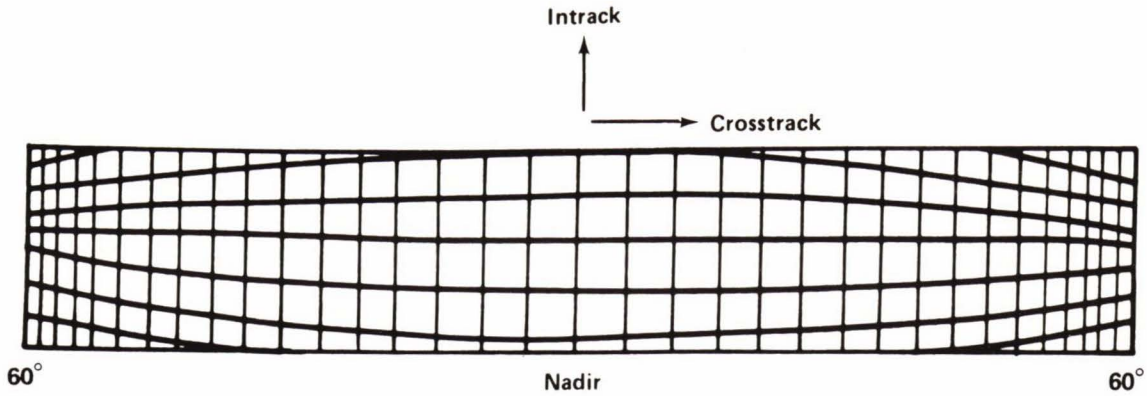
Aerial photo missions flown for mapping defoliation are usually flown with 55 to 70 percent forward overlap to permit stereo viewing. However, if defoliation mapping is done by monoscopic photo interpretation, it is only necessary to view every other photo along a flight line.

PRELIMINARY GROUND CHECKS

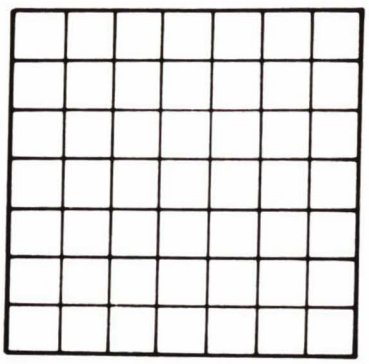
If time permits, photo interpreters will find it worthwhile to select one or two representative areas on the aerial photos to identify vegetation types and classify damage prior to the formal photo interpretation. These areas should be visited on the ground as soon as possible after viewing and classification to have the most meaningful comparison between photo classifications and actual on-the-ground conditions.

PHOTO ANNOTATION

The first task in photo interpretation is annotation. Annotation provides the means of keying the actual location of the photo on the earth's surface to a base map. This provides an index of the photo coverage and also helps to identify those areas lacking coverage.



(a) Vertical panoramic photograph



(b) Vertical frame photograph

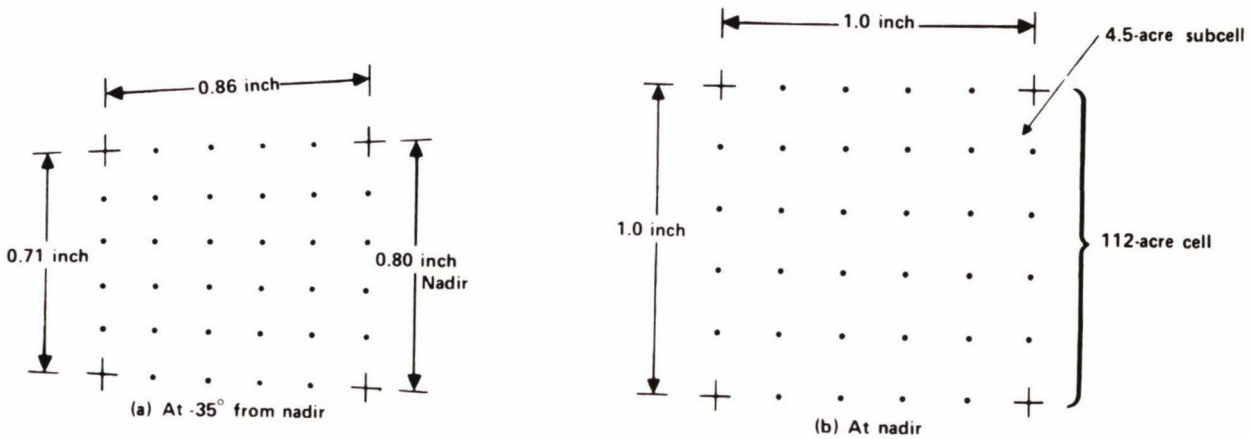


Figure 3 - Example of an equal area grid and two individual grid cells, one from nadir and one from 35° from nadir.

PRELIMINARY ANNOTATION

Usually by the time a photo interpretation team receives the aerial photographs some preliminary annotation has already been done. This is especially true in the case of surveys covering large areas, such as high altitude panoramic aerial photo missions involving several states.

Preliminary annotation usually is done on a small scale map, such as a 1:500,000 scale FAA aeronautical chart of the overall photo mission showing number of the first and last photo for each flight line. The approximate location of every tenth to twentieth photo may also be shown. This information is helpful for determining the general location of the photos and provides the basis for the more specific annotation which follows.

LOCATING THE PRINCIPAL POINT

The principal point of an aerial photograph is the point at the exact center of the photo image. Photo annotation is most commonly done by locating and marking the location of the principal points of aerial photos on base maps of the survey area. On 9-inch aerial photos, the principal point is found by placing a ruler over the opposite sets of fiducial marks which are located midway across the margins of the photo. The principal point is located where the lines from each pair of fiducial marks cross.

On panoramic aerial photography, which may be 5-1/2 inches by 39-1/2, 50 or 59-1/2 inches in size, the fiducial marks are a series of clear marks located in the black margins along each long axis of the photo. These correspond to nadir, the point directly underneath the aircraft, and each 20 degree interval, beginning at 10 degrees, either side of nadir. The principal point can be found using the three marks near the center of the photo that are closest together; the nadir mark is the one in the middle. Place a straight edge over the two nadir marks and measure half the width of the photo; 2.25 inches. This is the principal point.

TRANSFERRING THE PRINCIPAL POINT TO THE MAP

Find the principal point of a given photo frame on the base map of the survey area, then mark its location with a small dot or circle and indicate the the photo frame number. For 9-inch photos, the photo frame number is usually placed in the upper right or left hand corner of the photo, just below the data bank. On panoramic aerial photos, the photo frame number is found in the center of the data bank on the left hand side of the photo.

It is usually sufficient to only identify and transfer the location of every other photo on a flight line to the map. Normally, just the even numbered photos are annotated.

MAPPING HARDWOOD DEFOLIATION

IDENTIFYING VEGETATION TYPES

Separating areas of predominantly conifer forest from hardwood forests is easily done on CIR film because conifers register as a darker color than hardwoods. Stands of yellow pines, spruce, fir, or hemlock typically appear as a dark red brown or red violet color. Eastern white pine is somewhat lighter in color than the other conifers. Hardwood stands, by contrast, appear as bright red or magenta (Figure 4).

CLASSIFYING DEFOLIATION

Insect defoliation of hardwood forests appears as a gray or blue gray color on CIR film. These defoliated areas usually stand out in sharp contrast to the bright red or magenta of adjacent undamaged hardwood forests.

The lower limit of defoliation that is visible from the air or can be seen on aerial photos occurs when about 25-30 percent of the foliage has been removed. On CIR film these areas appear as a slight gray discoloration. As a higher percentage of the foliage is fed upon, the gray color becomes more distinct (Figure 5).

The simplest approach to classifying defoliation is to recognize three broad categories of damage; no visible defoliation, partial defoliation, and nearly complete defoliation.

It is a good idea to develop more complete descriptions of each damage class to aid photo interpreters. These descriptions may vary somewhat depending on the insects feeding habits. In recent years, defoliation by the gypsy moth has been classified on high altitude panoramic CIR aerial photos using class definitions developed by the Pennsylvania Bureau of Forestry, and widely used in the Northeast, for aerial sketch mapping. These classes are described as follows:

NO AERIALLY VISIBLE DEFOLIATION.

MODERATE AND WIDESPREAD - Pure host type with first noticeable defoliation visible from aerial observation (generally 30-60 percent defoliation).

HEAVY AND WIDESPREAD - Pure host type with nearly total loss of host foliage (generally >60 percent defoliation).

INTERPRETATION ERRORS

Photo interpreters should keep in mind that forest ecosystems are complex and many phenomena can occur which might resemble defoliation or make defoliation appear more severe than it actually is. A few of the more commonly occurring phenomena which somewhat resemble defoliation and cause interpretation error are:

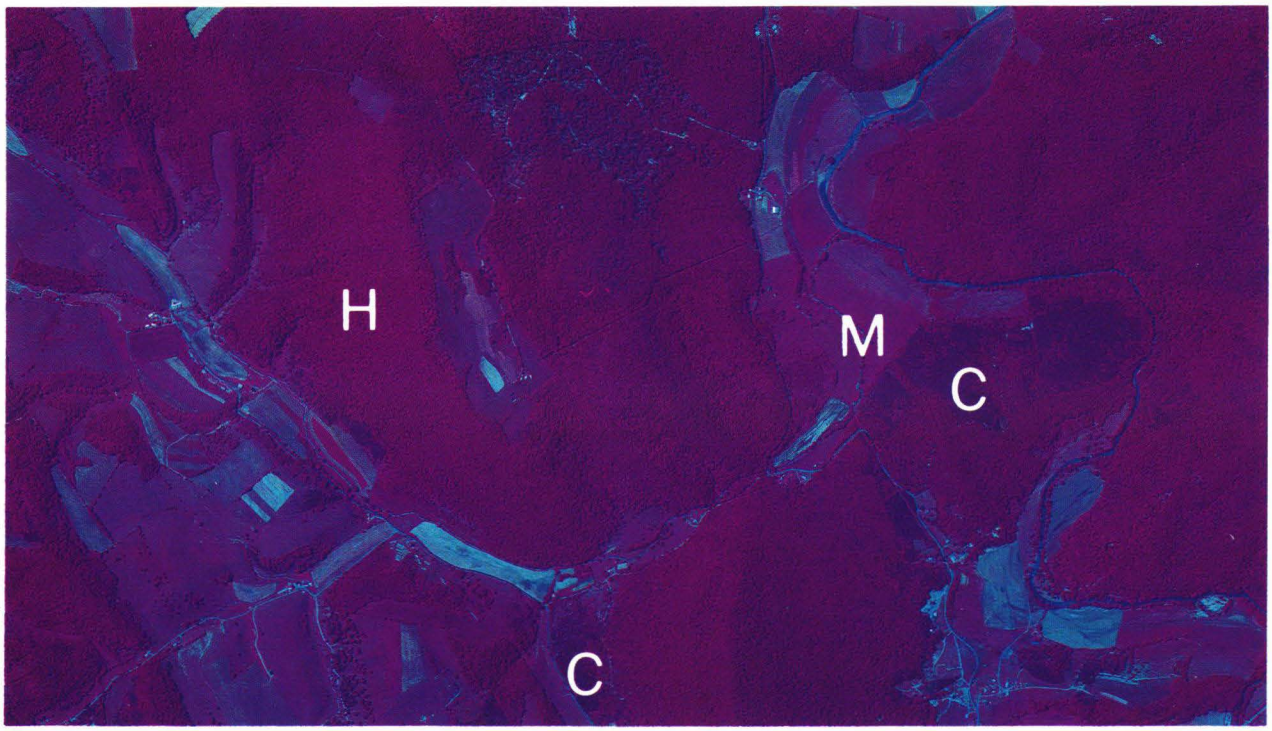


Figure 4 - Portion of a CIR panoramic aerial photo over western Maryland showing vegetation types. Dark areas (C) are conifer stands; brilliant red areas (H) are hardwood forests; and lighter colored areas (M) are grassy meadows.

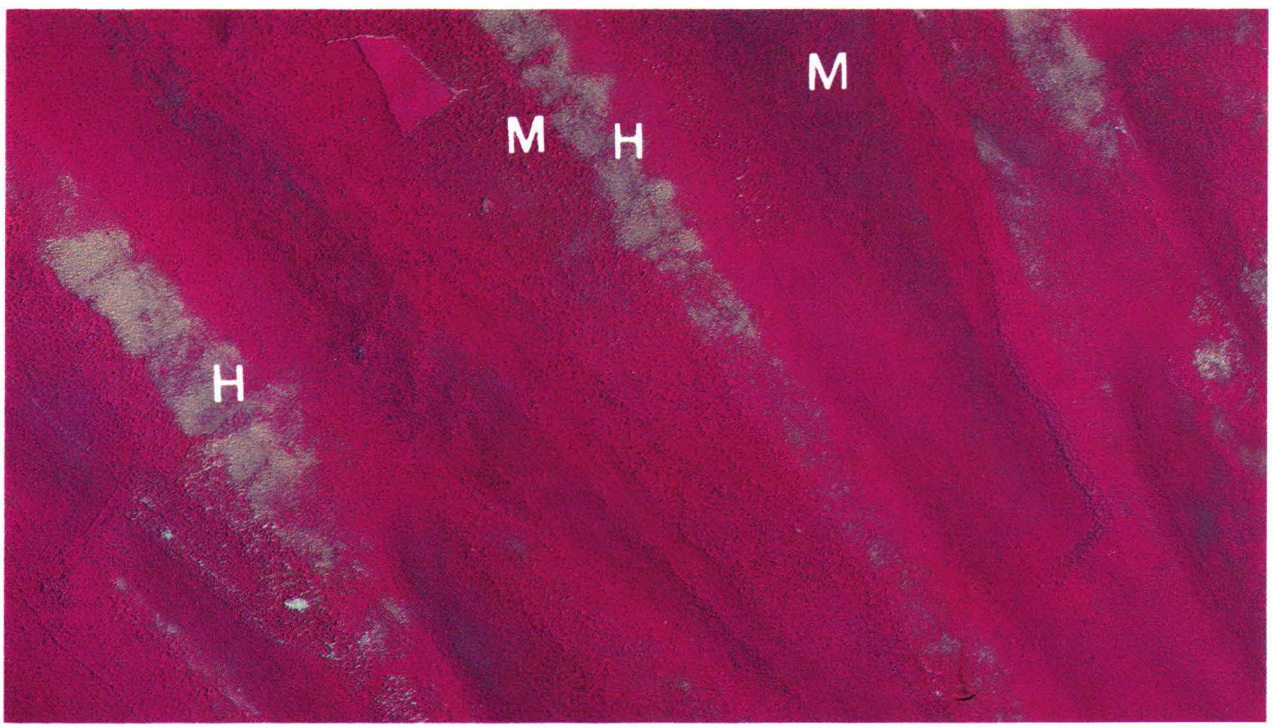


Figure 5 - Hardwood forests in central Pennsylvania defoliated by gypsy moth. Moderate (30-60%) defoliation appears as areas of slight gray discoloration (M) heavy defoliation (>60%) appears as distinct gray patches (H) where almost all of the foliage has been removed.

EFFECT OF SLOPE ON CLASSIFICATION OF DEFOLIATION - Where terrain is mountainous the aspect of a slope relative to the sun angle can influence the intensity of color for both healthy and damaged vegetation. Defoliated slopes directly facing the sun are often distinctly lighter in color than are shaded slopes. Photo interpreters should take precautions to classify color shifts caused by different exposures to the sun as different intensities of defoliation (Figure 6).

TREE MORTALITY - A major source of photo interpretation error involves confusing defoliation with areas of dead trees, especially areas of recent tree mortality. Since tree mortality often follows several successive years of insect defoliation, both types of damage may be present in the same area. The following guidelines, while not intended to be absolute rules, may provide some help in separating tree mortality from defoliation (Figure 7).

DEFOLIATION -

1. Often widespread, covering large areas.

2. Pattern of gray discoloration is relatively uniform.

3. Edges of defoliated areas tend to be somewhat indistinct or blurred.

TREE MORTALITY -

1. Is usually confined to more localized areas.

2. Pattern of discoloration tends to be less uniform. Often there is a mottled appearance due to the presence of holes with dead trees in an otherwise uniform canopy of living trees.

3. Edges of mortality areas tend to be more distinct.

CHANGES IN FILM EXPOSURE - Variations in exposure can occur across an aerial photo. This is especially true of high altitude panoramic aerial photos taken when the sun angle is low. These variations can cause marked shifts in color balance of CIR film. In some instances conifer stands on overexposed portions of a photo can be significantly lighter in color than on those areas where the exposure is optimal. In extreme cases conifer stands can take on a blue gray color on overexposed sections of film that is more typical of defoliated hardwoods (Figure 8). Under these conditions, photo interpreters may have difficulty in separating the two, especially on panoramic aerial photos. When in doubt, examine individual crowns under magnification; if they appear to have foliage, and bare stems and branches are not visible, they are probably light colored conifers.

OTHER SOURCES OF ERROR - Other phenomena which could be confused with insect defoliation include:

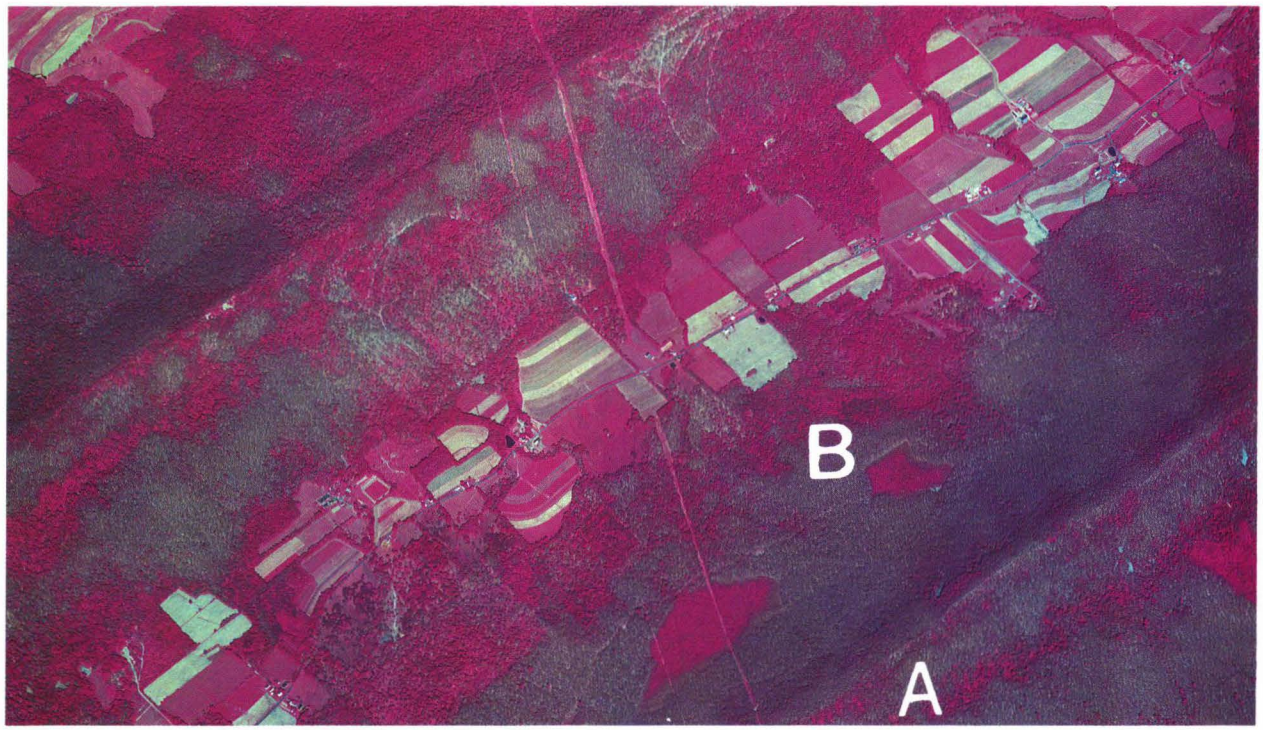


Figure 6 - Aspect of a defoliated slope can affect the hue of gray on CIR film. On this scene, areas A and B both have been heavily defoliated by gypsy moth. Area A is distinctly lighter in color due to the fact that the slopes are exposed to direct sunlight.

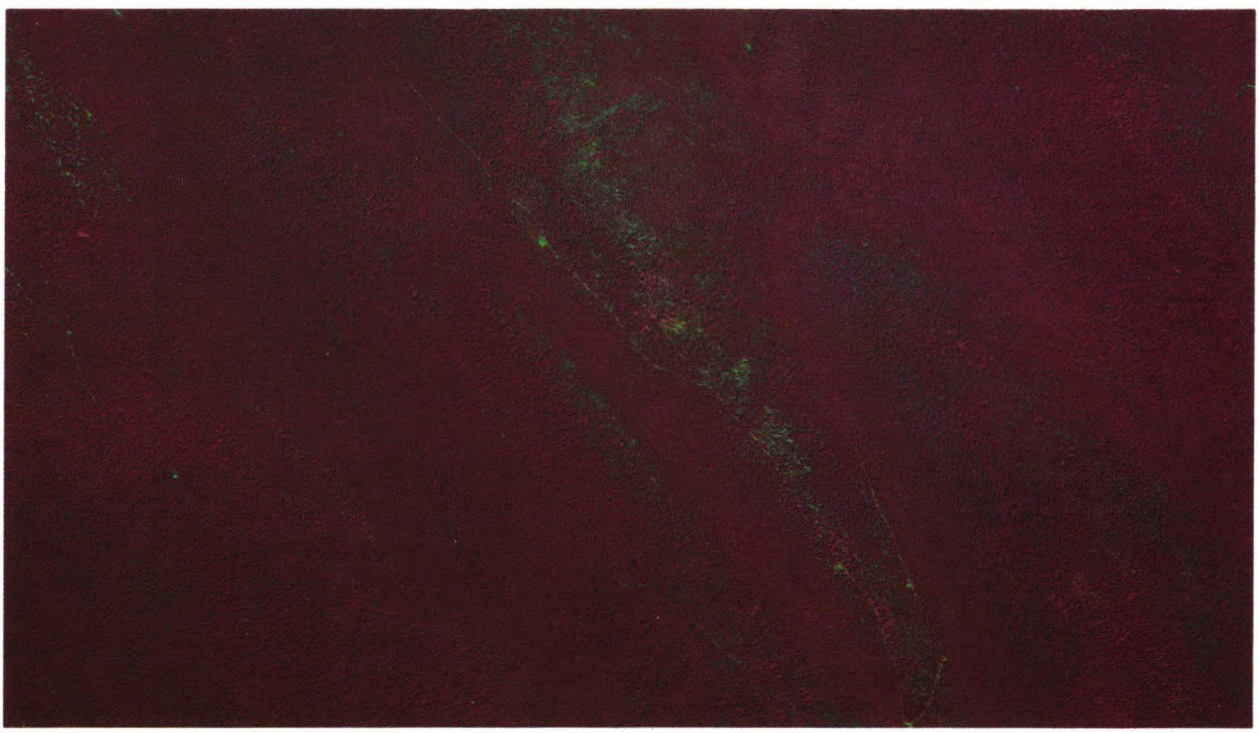


Figure 7 - Hardwood tree mortality in central Pennsylvania. Note that pattern of discoloration is less uniform than in Figures 5 and 6 due to presence of surviving trees.

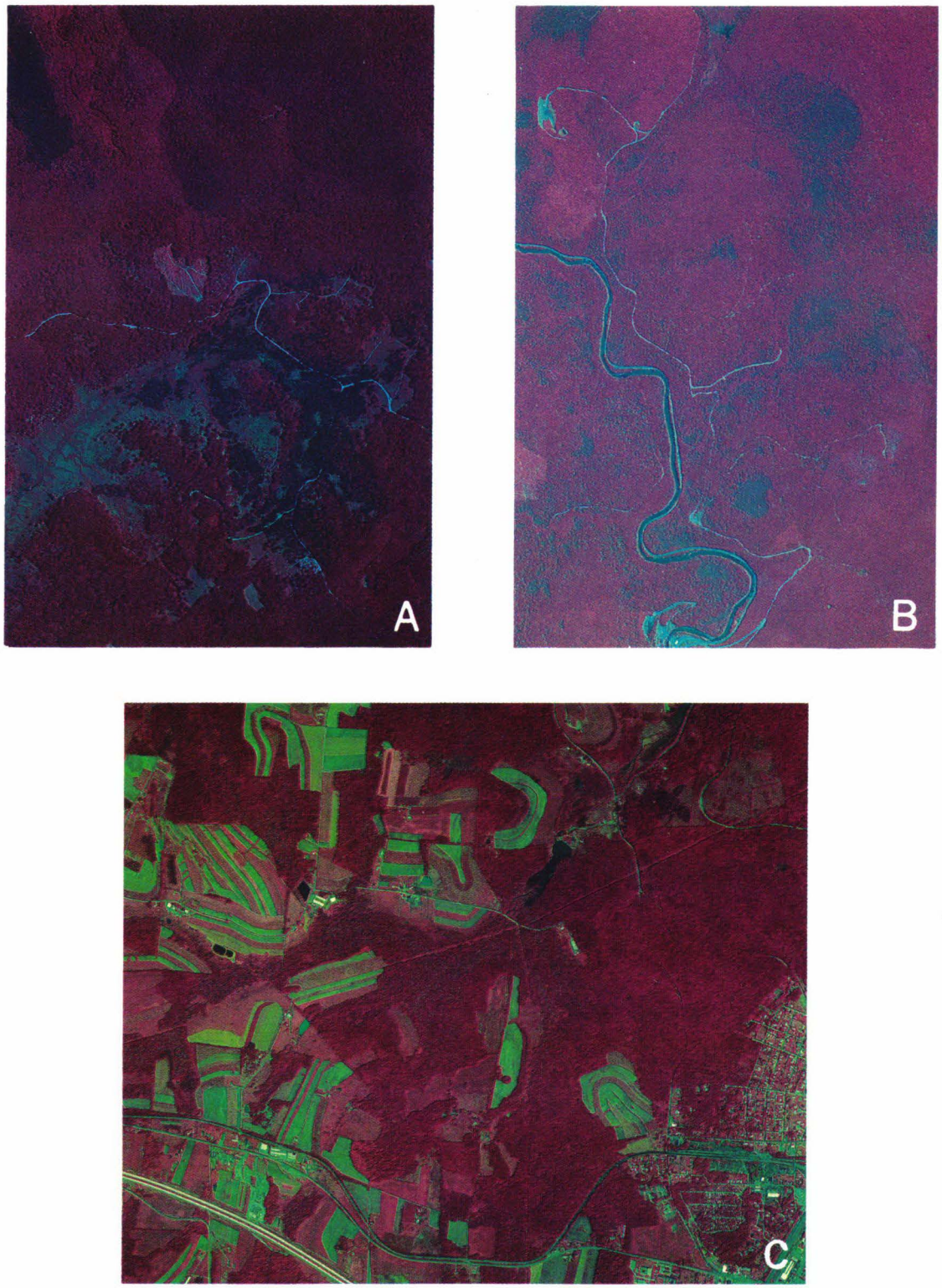


Figure 8 - Color variations in conifer stands. A. Stands of red spruce on the Monongahela National Forest in West Virginia on a portion of a frame of panoramic photography that is optimally exposed appear distinctly darker than surrounding hardwood stands. B. A portion of the same photo frame that has been slightly overexposed. Note color shift in red spruce stands. C. A stand of eastern white pine and hemlock along a creek bottom near Cresson, Pennsylvania, that is unusually light in color. This stand was erroneously classified as hardwood defoliation by photo interpreters.

1. Foliar injury due to late spring frosts, especially in high elevation areas.

2. Partial foliation of hardwoods at high elevations due to a late Spring.

3. Selectively cut timber stands may resemble partial defoliation, especially when viewed monoscopically.

4. Rock outcrops, talus slopes, and bare ground on the side slopes of ridges may, on occasion, resemble defoliation.

5. Areas of recent fire damage, especially where new growth in the understory has masked scorching on the ground (Figure 9).

6. Refoliation can mask the occurrence of complete defoliation even though replacement foliage is somewhat smaller and paler in color than the first crop of foliage.

7. Vegetation recently killed by herbicides.

8. Damage caused by hail or severe winds.

9. Concentrated areas of foliar injury or tree mortality caused by atmospheric deposition of pollutants in the vicinity of industrial sources.

MAP TRANSFER

As defoliated areas are classified, they should be transferred to a base map. This can be done in one of two ways; by sketch mapping the location of defoliated areas on the map, or with the aid of a transfer device such as a zoom transfer scope.

Sketch mapping is the simplest form of map transfer and should provide insect defoliation maps of sufficient accuracy for most purposes. The location of defoliated areas are drawn by hand on the base map, using whatever cultural or topographic features are available, as reference points. This is essentially the same procedure that is used when sketch mapping the location of damaged areas from small aircraft (Figures 10 and 11). However, the photos provide the opportunity for more detailed scrutiny which can never be achieved by aerial sketch mapping.

If boundaries of defoliated areas must be transferred with greater accuracy than can be obtained by sketch mapping, then a device such as a zoom transfer scope can be used. This instrument has a series of optics and mirrors which permit direct overlay and simultaneous viewing of photos and maps of different scales (Figure 12). While this equipment will provide for greater accuracy in transfer of damaged areas, it is expensive, not often available to a team of photo interpreters at a field location, and the transfer process is considerably slower than sketch mapping.

Figure 9 - Recently burned area in central Pennsylvania (F) contrasted with areas of moderate (M) and heavy (H) gypsy moth defoliation.

Figure 10 - A photo interpreter classifies gypsy moth defoliation on a panoramic aerial photo and transfers location of damage to a map base using a sketch map technique.

ASSESSMENT OF TREATMENT EFFECTIVENESS

Aerial photographs can be used to assess the amount of foliage protected by the application of chemical or biological insecticides directed against defoliating insects. This can be done if the following conditions exist:

1. Areas surrounding the treatment areas are of the same forest cover type.

Figure 11 - Portion of a panoramic aerial photo of central Pennsylvania showing gypsy moth defoliation and accompanying USGS 7.5 minute topographic map showing defoliation classification by photo interpreters (4 = moderate, 6 = heavy).

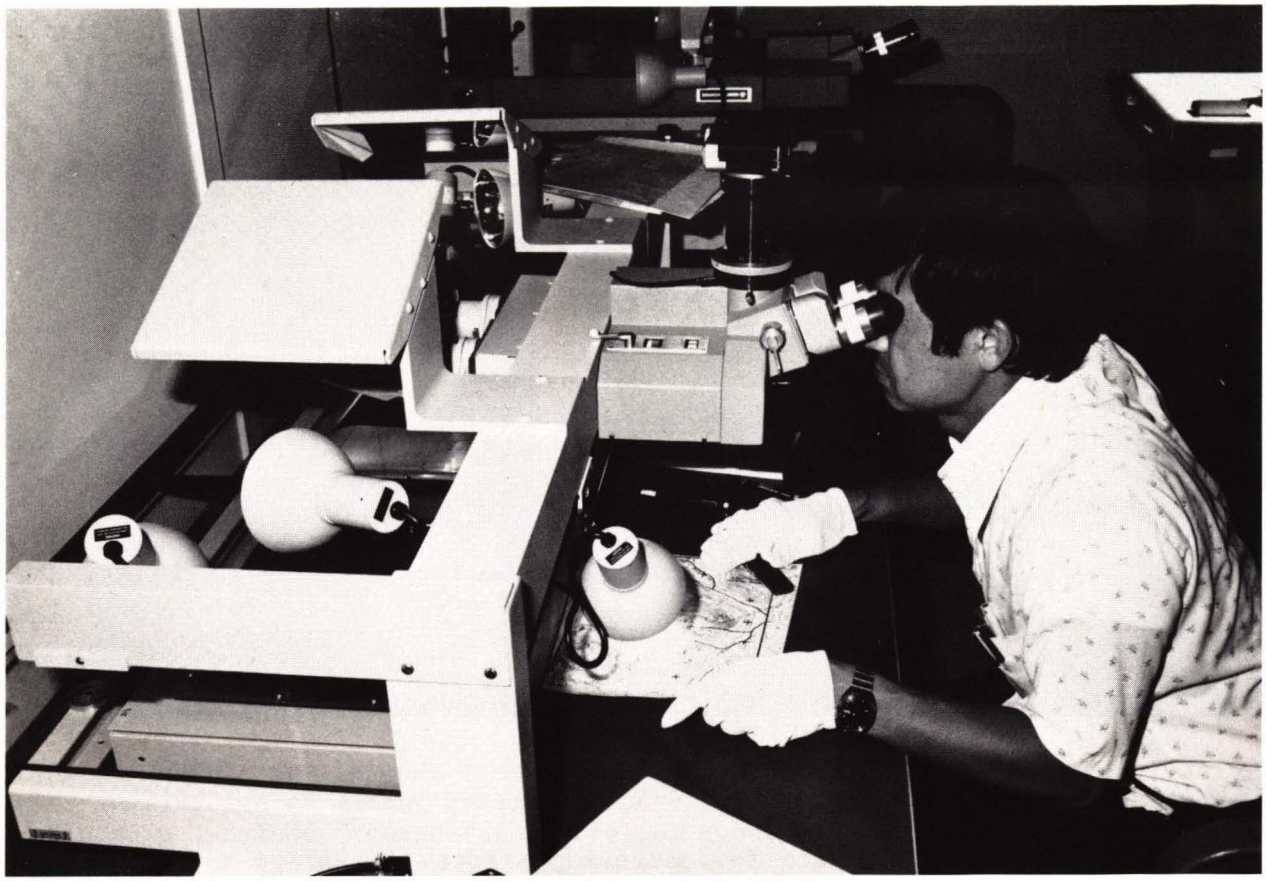


Figure 12 - Transferring polygons of defoliation from photos to maps with a Bausch and Lomb zoom transfer scope.

2. Prior to treatment both sites contained populations of the target insect capable of causing similar defoliation.

3. Populations of the target insect are high enough to cause defoliation which is visible from the air.

Several relatively simple, yet effective means are available for displaying and analyzing the results of photo interpretation to determine treatment effects.

THE AERIAL PHOTO AS A "STAND ALONE" PRODUCT

The old saying, "A picture is worth a thousand words," was never more appropriate than for this particular application of aerial photography. In

many cases the treatment effect is so obvious that nothing more need be done than to display the photograph. This is especially true if the insecticide is highly effective and an area of protected foliage occurs within the boundaries of the treated area while surrounding stands are almost completely defoliated (Figure 13-A).

A measure of the quality of treatment may also be possible. Areas missed during aerial spray operations can appear as distinct bands of defoliation. Areas adjacent to treatment blocks which receive spray drift often appear as zones of complete or partial foliage protection which extend beyond the spray block boundaries (Figure 13-B).

NARRATIVE DESCRIPTIONS

Another approach is to describe the pattern of damage seen on aerial photographs relative to land features and treatment area boundaries. For example, a description resulting from the interpretation of a panoramic aerial photograph of an area treated for control of gypsy moth in central Pennsylvania in 1981 was as follows:

> "MIFF-1 - Areas of moderate and heavy defoliation occur to the north and west of block. Most of forest area within block has no visible defoliation. A small area of heavy defoliation extends south into the block from a ridge parallel to Furnace Run. Low lying areas to east of the block have no visible defoliation."

DEFOLIATION MAPPING

The most detailed approach for assessing effects of sprays is to prepare maps showing varying intensities of damage relative to the boundaries of the treatment area (Figure 14). The boundaries of the spray blocks are plotted on the base map, then the damage is transfered to the base map using the sketch mapping techniques or a zoom transfer scope as described in the preceding section. The area, or proportion of area, in each block receiving various intensities of defoliation can then be obtained, summarized, and compared (Table 2).

Observing treatment effects on aerial photos is most apparent when relatively small blocks are surrounded on all sides by untreated areas of similar vegetation type and target insect population density. These conditions occur most typically when field experiments are conducted to compare efficacy of various materials and dosage rates.

In operational control programs, treatment blocks are often large and may be irregular in shape, conforming to the distribution of susceptible host type or landownership boundaries. Under these circumstances, even highly effective treatment results may not always be apparent on aerial photos. Use of aerial photos to assess treatment effects of large scale operational control programs is still worthwhile however, because it is usually logistically impossible to

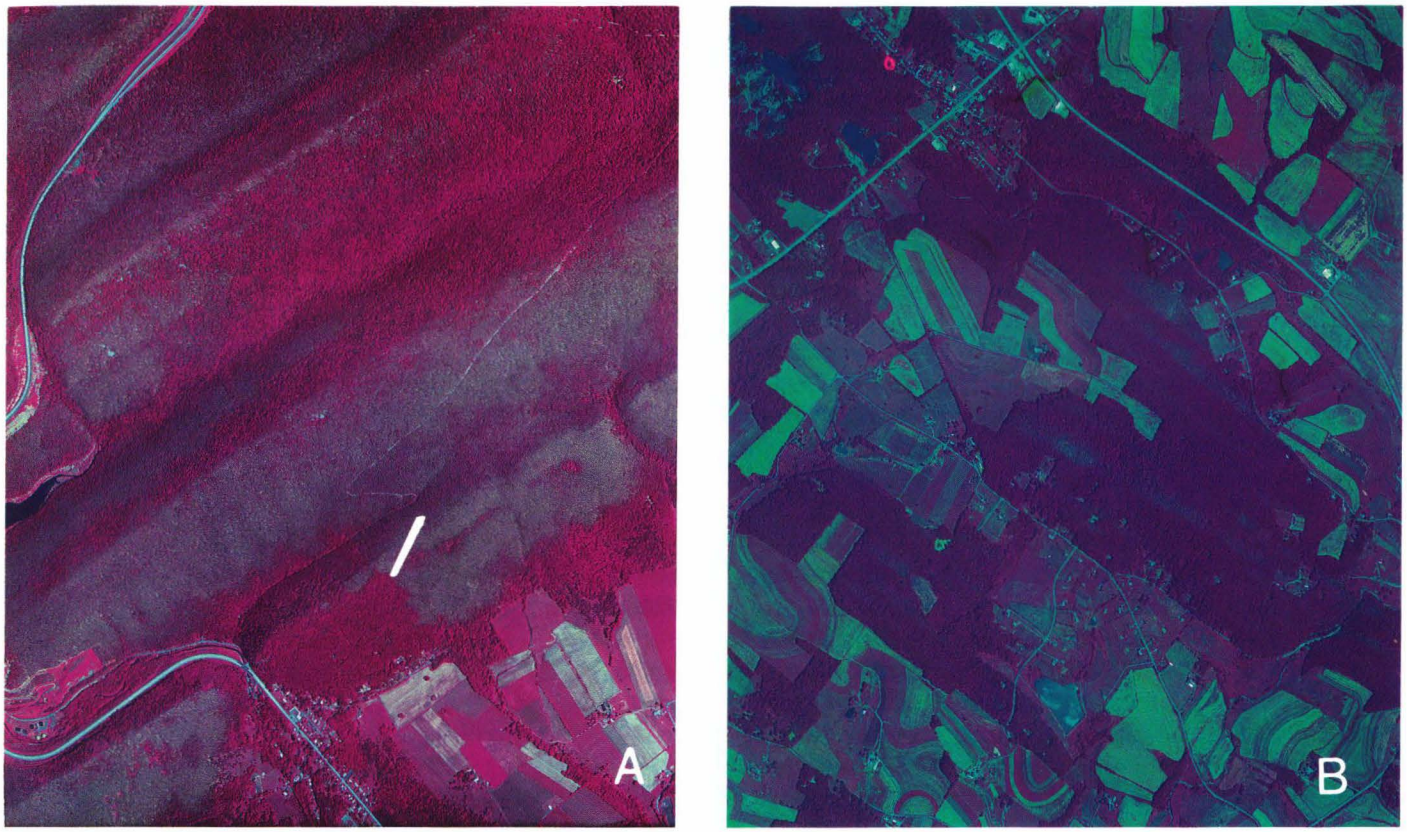


Figure 13 - A. Forested area (arrow) in central Pennsylvania protected from defoliation by application of aerial sprays to control gypsy moth infestation. B. Spray block in Maryland treated for control of gypsy moth. Note alternating bands of undamaged and defoliated stands probably due to an inadequate swath interval of the spray aircraft.

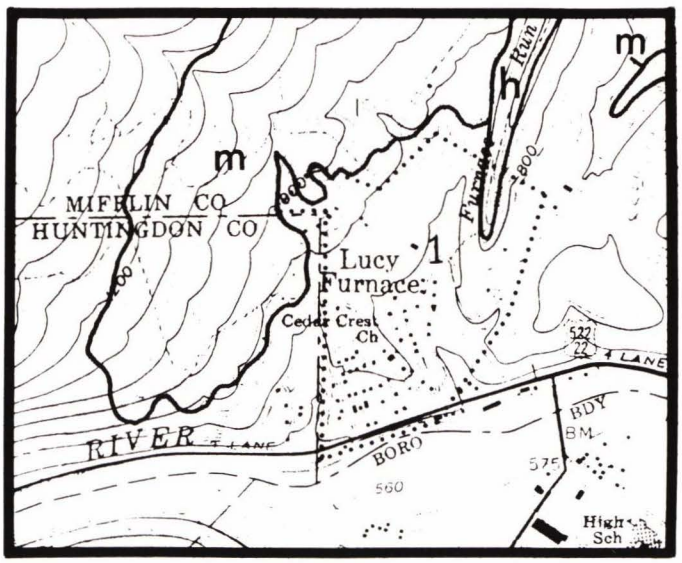


Figure 14 - Map showing location of defoliated areas (m = moderate, h = heavy) relative to boundaries of a spray block (dotted line).

Table 2 - A Sample Display of Damage Within Areas Treated for Control of Gypsy Moth in Mifflin County, Pennslyvania 1981.

Block No.	Total Area Within Block (Acres)	Net Forested Area (Acres)	Area Defoliated (Acres)		
			Moderate	Heavy	Total
1	129.51	74.05	0	9.8	9.8
2	72.00	49.42	0	0	0
3	26.70	.92	0	0	0
4	60.86	44.18	0	0	0
5	6.15	6.08	6.01	0	6.01
6	11.44	3.57	0	0	0
8	46.00	40.86	0	3.50	3.50
9	111.96	69.03	0	31.62	31.62
10	24.59	18.75	4.41	0	4.41
11	54.55	54.54	48.08	6.44	54.52
13	51.33	30.71	8.65	0	8.65
14	68.45	53.56	0	0	0
17	60.28	26.95	2.52	0	2.52
18	70.93	31.33	0	0	0
19	81.43	67.32	0.16	0	0.16
20	47.22	34.25	0.12	0	0.12
21	64.47	48.08	9.97	0	9.97
23	33.63	22.91	0	0	0
24	166.18	104.40	0	0	0
25	215.50	184.67	0	0	0
26	191.19	102.16	7.71	0	7.71
27	7.57	4.02	0	0	0
28	28.39	26.12	0	0	0
29	32.40	12.68	0	0	0
30	29.96	13.76	0	0	0
31	183.49	105.97	0	0.02	0.02
32	117.78	98.22	5.75	0	5.75
33	79.61	45.33	0	0	0
34	49.58	40.09	10.59	0	10.59
35	57.46	40.58	0	0	0
36	105.62	66.67	7.37	0	7.37
37	76.48	19.13	0	0	0
38	63.41	25.13	0	0	0
39	175.75	33.67	0	0	0
40	23.24	18.10	0	0	0
41	129.82	97.44	0	0	0
42	16.80	11.85	0	0	0
43	67.04	57.44	0	0	0
44	82.40	67.27	0	2.45	2.45
45	248.24	248.24	0	12.81	12.81

examine all of the treated areas on the ground. In addition, aerial photography permits evaluation of areas treated for defoliator control at the same time defoliation mapping is done.

GROUND DATA

Ground data, while not essential for mapping forest defoliation from aerial photos, may be desirable for several reasons. As previously mentioned, it is worthwhile to do a preliminary classification of defoliation and related conditions which might resemble defoliation on a small sample of photos. These should be field checked by members of the photo interpretation team to help familiarize them with on-the-ground conditions. This informal exercise is of value especially if the photo interpreters are relatively inexperienced or not familiar with the survey area.

Another reason for acquisition of ground data is to confirm the identity of the insect responsible for the damage. Obviously, the only thing that can be ascertained from aerial photos is that defoliation is present. The causal agents responsible for the damage cannot be identified from photos alone. In most cases, by the time a photo mission is scheduled, the identity of the defoliator is already known. However, there is always the possibility that some areas of defoliation may be the result of some other agent; another insect or insect complex, herbicide injury, etc. Locations which should have high priority for ground checking include:

1. Areas of defoliation far removed from the main body of the infestation.

2. New defoliation in areas which do not have a prior history of infestation.

3. Damage which may be questionable (i.e., suspected of being caused by a late spring frost, tree mortality rather than defoliation, etc.).

4. Defoliation appearing in areas where the host type or topographic conditions are known to be significantly different from the established area of infestation.

5. Areas of high value such as parks or special use areas.

Supplemental ground data for assessing treatment effects on aerial photos is also desirable. Relying solely on aerial photos alone without knowledge about natural fluctuations in insect population density or condition of the host plant can lead to erroneous conclusions about treatment effects. Such fluctuations must be accounted for with ground sampling. On the other hand, a disadvantage of relying solely on defoliation data from small ground plots is that the data from isolated points within a block may vary greatly from one to another and from the average value of the block as a whole. A combination of photo interpretation and ground plot evaluation always provides a better understanding of treatment effects.

Ground plots where data is taken on damage intensity can be compared to damage classification of the same point on aerial photographs using simple error or similarity matrix (Table 3).

Sometimes lack of access into a treated area severely limits acquisition of adequate ground data. In such cases, aerial photography may be the only means available to gain some insight as to the effectiveness of the treatment.

Table 3 - An Example of an Error Matrix Comparing Aerial and Ground Defoliation Estimates in Spray and Check Blocks from a Pilot Control Project.

Intensity Class on Ground Plots (Number)	Intensity Class on Aerial Photos (Number of Plots)			
	Undamaged	Partial	Heavy	Subtotal
Undamaged	24a	3	0	27
Partial	4	15a	2	21
Heavy	0	10	16a	26
Subtotal	28	28	18	55/74 = 74%

a - Denotes agreement between aerial and ground classification

ACKNOWLEDGMENTS

We thank D.R. Kucera, USDA Forest Service, Forest Pest Management, Northeastern Area, Broomall, Pennsylvania; G.N. Mason, USDA Forest Service, Northeastern Forest Experiment Station, Morgantown, West Virginia; C.L. Morris, Virginia Division of Forestry, Charlottesville, Virginia; and J.W. Quimby, Pennsylvania Bureau of Forestry, Harrisburg, Pennsylvania, for their constructive review of this manuscript.

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